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PROBLEM ANALYSIS - PROJECT FS-INT-1703

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Revised August 24, 1965

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PROBLEM ANALYSIS FOR PROJECT FS-INT-1703

Management, ecology, and physiology of salt-desert shrub, sagebrush-grass, and pinyon-juniper rangelands of the Great Basin and on the Colorado River drainages of Eastern Utah and Southwestern Wyoming (salt-desert shrub, sagebrush-grass, and pinyon-juniper ranges)

by

Neil C. Frischknecht

SCOPE

Field Embraced by Project

The three major range types encompassed by Research Project 1703 are the salt-desert shrub, sagebrush-grass, and pinyon-juniper. They occupy the low and intermediate elevational rangelands of the Great Basin and Colorado River drainages of Utah, Nevada, and western Wyoming. Parts of three main physiographic provinces are found within this area; namely, the Basin and Range, the Colorado Plateau, and the Rocky Mountain. The climate is generally arid or semi-arid because of mountain barriers formed by the high Sierra Nevada on the western boundary, the Mogollon Rim on the south, and the Rocky Mountains on the east (Thomas 1962). Within the scope of the project, the big sagebrush-grass and salt-desert shrub types probably occupy 30 million acres each, and the pinyon-juniper type 20 million acres.

The area encompassed by the project in western Utah and Nevada is unique because of the basin and range topography. There are more than a hundred basins separated by fault-block mountain ranges extending in a north-south direction (Billings 1949). Drainage within the area is into playas, saline flats, or permanent lakes within the basins. Forest or woodland vegetation, much of which is pinyon-juniper woodland, is found mainly on the slopes and crests of the intervening mountain ranges. Woodbury (1947) has indicated that the elevational limits of the pinyon-juniper type may vary from 3,200 to 8,400 feet above sea level and that annual precipitation may vary from 10 to 25 inches.

Utah juniper (Juniperus osteosperma) is the most prominent tree in this type within the project area. Two-leaf pinyon (Pinus edulis) is frequently associated with Utah juniper in the eastern half of Utah, but it is replaced with single-leaf pinyon (P. monophylla) in western Utah and Nevada. One-seed juniper (J. monosperma) tends to replace Utah juniper in southern Utah. Rocky mountain juniper (J. scopulorum) and low-growing juniper (J. communis) may be found at the upper edge of the type in Utah and northward. Important understory species include big sagebrush (Artemisia tridentata), black sagebrush (A. nova), serviceberry (Amelanchier alnifolia), bitterbrush (Purshia tridentata), Gambel oak (Quercus gambeli), mountain mahogany (Cercocarpus spp.), Indian ricegrass (Oryzopsis hymenoides), wheatgrasses (Agropyron spp.), bluegrasses (Poa spp.)

needle-and-thread (Stipa comata), penstemon (Penstemon spp.), peavine (Lathyrus spp.), plus many lesser forbs.

The estimated 30 million acres of sagebrush-grass would include big sagebrush (A. tridentata) as the main brush species. Other locally prominent shrubs include several species of rabbit-brush (Chrysothamnus spp.), bitterbrush (Purshia tridentata), horsebrush (Tetradymia spp.), four-wing saltbush (Atriplex canescens), and some lesser shrubs. Principal grasses include bluebunch wheatgrass (Agropyron spicatum), bluestem wheatgrass (A. smithi), Great Basin wildrye (Elymus cinereus), Idaho fescue (Festuca idahoensis), bluegrasses (Poa spp.), Indian ricegrass (Oryzopsis hymenoides), and needle-and-thread grass (Stipa comata). Principal forbs include arrowleaf balsamroot (Balsamorhiza sagittata), northern sweetvetch (Hedysarum boreale), hawksbeard (Crepis spp.) peavine (Lathyrus spp.), plus many lesser forbs.

The big sagebrush-grass type is found mainly between 4,300 and 7,200 feet elevation where average precipitation ranges from 6 to 15 inches annually. It occurs, also, at higher elevations throughout the mountain brush, aspen, and into the subalpine zones, but these higher areas are presently considered to be outside the scope of this project. The pinyon-juniper and sagebrush-grass types are frequently interspersed, particularly on alluvial fans, which are common features of the landscape. Generally, the sagebrush-grass type, and in many places, the pinyon-juniper, adjoin the upper reaches of the salt-desert shrub type.

Shrubs of the salt-desert-shrub type include mostly low-growing species such as shadscale (Atriplex confertifolia), winter-fat (Eurotia lanata), bud sagebrush (A. spinescens), small rabbit-brush (C. stenophyllus), black sagebrush (A. nova), and snakeweed (Gutierrezia sarothrae). Herbaceous species include Indian rice-grass (O. hymenoides), galleta (Hilaria jamesi), sand dropseed (Sporobolus cryptandrus), bottlebrush squirreltail (Sitanion hystrix), globe mallow (Sphaeralcea spp.) and many lesser forbs.

The same general relationship between the three vegetation types exists in the Colorado River drainage as in the Great Basin. The salt-desert shrub occupies the drier, lower-lying areas with the sagebrush grass and pinyon-juniper interspersed immediately above. Unlike the Great Basin, broad mesas and buttes separated by sharp scarps and sometimes great distances, characterize the landscape. Some of the most extensive stands of pinyon-juniper occur within this drainage.

Soils of the salt-desert shrub type are principally gray desert soils having an accumulation of carbonates at shallow depths (Billings 1949). Soils in the sagebrush-grass type may vary between the gray desert and brown soil groups. They are usually well drained and free from alkalinity or salinity, at least near the surface. The pinyon-juniper type frequently occupies shallow stony soils of the mesas, mountainsides, foothills, and it has greatly extended its range into deeper soils of the sagebrush-grass type.

Resources, Their Value and Uses

Lands within the scope of this project provide grazing for most of the range livestock within the area for approximately 9 months of the year, and in some cases, 12 months. The sagebrush-grass and pinyon-juniper lands are used mainly for spring-fall grazing, and the salt-desert shrub type for winter grazing. Considering all of Utah's rangelands, the value of forage consumed by approximately 438,000 cattle and 1,300,000 sheep is estimated to be worth \$30 million annually (USU 1960⁶). A similar figure might evaluate the forage consumed annually by approximately 500,000 cattle and 200,000 sheep in Nevada.

In addition to livestock, deer and other big-game animals graze the sagebrush-grass and pinyon-juniper types for approximately 6 months of the year. All of Utah's rangelands provide yearlong grazing for approximately 375,000 big-game animals (USU 1960⁶). The total figure for big-game animals in Nevada would be somewhat less than for Utah, but here too, forage for big game is an important resource.

Some lands encompassed by this project have values for agriculture which is of higher priority than grazing, but lack of water for irrigation restricts the number of acres farmed. Utah has a total of 5,395,000 acres of arable lands (USU 1960⁶), all of which lie within the vegetation types encompassed by this project, but only about 37 percent of Utah's arable soils are cropped. Likewise,

some 800,000 acres of irrigated land in Nevada represents probably less than half of the arable lands of that state. The knowledge that the area possesses a surplus of arable land compared with the water resources will place increasing importance on wise and efficient use of water. This means also that some lands now used for grazing will have agricultural value if additional water becomes available. Within these states, most of the water comes from higher mountain areas, and the vegetation types within this project contribute very little water to the total supply.

In addition to range forage, the products from the pinyon-juniper type include fuel, fence posts, Christmas trees, and charcoal. Also, some of these lands have certain potential for recreation, mainly around water storage reservoirs.

LAND USE (MANAGEMENT) PROBLEMS

Social and Economic

An important question is, "How will the rapidly expanding population affect use of western rangeland, more particularly the lands encompassed by this project?" Utah's population, which increased 62 percent from 1940 to 1960, is expected to increase another 59 percent by 1975. The millionth person was added to the state's population in 1964. Ninety-five percent of the 1940-1960 increase was in four counties along the Wasatch front (Weber, Davis, Salt Lake, and Utah). These counties now contain 75 percent of the state's population, but less than 5 percent of the total area. In contrast, 14 rural counties comprising 52 percent of the state's area, contain only 7.4 percent of the state's population (Blanch 1962). It can be expected that within the foreseeable future, most of Utah's increase in population will be in the suburbs along the Wasatch front. Thus, land taken up for residential areas would involve very little of the lands now used for livestock grazing, but it may continue to encroach upon the narrow but important belt of game winter range along the Wasatch front.

In Nevada, also, most of the population is confined to relatively small areas. Over three-fourths of the total population is found in Clark and Washoe Counties in and near the cities of Las Vegas and Reno, respectively. The combined land area of these two counties represents only 13 percent of the state's total (State of

Nevada 1958). The largest future increases are expected to be concentrated within these two counties.

Outlets for Products

Aside from the local markets consuming a much larger part of the total livestock production, there is a great potential market in California for Utah and Nevada products. One-fourth of the population of the 17 western states now resides in California, and an anticipated increase of 67 percent by 1975 will create a much larger western market (Utah State University 1960⁶). This will afford tremendous opportunity for cheaper marketing costs, which is a great advantage to producers in meeting competition.

Land Ownership

The following table shows land ownership in percentage of the total area for Utah and Nevada, encompassing about 52 and 71 million acres, respectively:

	<u>Utah</u>	<u>Nevada</u>
Federal	71.2	87.1
Private	14.5	5.0
State	6.7	0.2
Farming	3.6	0.8
Railroad lands	0.0	2.1
Miscellaneous	<u>3.9</u>	<u>4.8</u>
	100.0	100.0

These two states have the largest percentages of federally-owned land of any of the 48 states. The Bureau of Land Management alone administers approximately 50 percent of the land in the state of Utah and an even larger percentage in Nevada. Certainly, it

administers most of the land within the scope of this project. Most of the privately-owned land within these states lies within the sagebrush-grass and pinyon-juniper types. Low elevational national forest range is found also within these vegetation types.

A recent trend in Utah at least, is the purchase by the State Fish and Game Department of privately-owned pinyon-juniper and sagebrush lands which are judged to be deer winter range. This amounts to sizeable acreages in certain localities such as Sanpete and Millard counties where upwards of 15 and 19 thousand acres, respectively, have been purchased. In 1965, the total acreage owned by the State Fish and Game Department was around 200 thousand acres scattered throughout the state. The department also leases land from the Utah State Land Board on the same basis as private operators, so that in some areas it has direct control over relatively large contiguous blocks in the pinyon-juniper and sagebrush-grass types.

History of Range Utilization and Programs for Rehabilitation

Overgrazing and other uses have caused serious depletion of lands within the scope of this project. The sagebrush-grass and pinyon-juniper types are most depleted of herbaceous species of any lands within the Intermountain region. These areas are used by livestock in both spring and fall enroute to summer and winter ranges, and some of these lands are grazed by livestock all winter where snow conditions permit. In addition, big game use these areas for about 6 months during the fall, winter, and early spring. On the most critical areas, sagebrush has even been killed, and juniper trees are high-lined by deer in winter. Large acreages have been subjected to other abuses such as fire, and plowing, with subsequent abandonment of land marginal for cultivation. Such lands now support mostly annual weeds and brush species of low forage value. Thus, these ranges as a whole are producing far below their potential in both quantity and quality of forage.

Livestock and big-game losses due to poor nutrition are greatest within these types, and these areas become the graveyard for many animals in late winter and early spring, particularly in years having severe winters. Much of this land in both public and private ownership has been depleted of good forage and vegetal cover for many years, and soil erosion is accelerated. In some areas depletion of both vegetation and soils is still in progress. If overgrazing continues, these ranges will eventually become "bankrupt" of soil as well as good vegetal cover. It only follows that livestock enterprises dependent upon these areas will also become "bankrupt".

Various programs have been initiated and sizeable funds provided to encourage range rehabilitation. The Anderson-Mansfield Reforestation and Revegetation Act of 1949 (USDA 1964), provided \$40 million for the revegetation of some 4 million acres of depleted rangelands on national forests of the West. This amount was to be expended during the 15-year period 1950-65, and thereafter appropriations were to be made as needed. The depleted lands in need of revegetation were considered "potentially capable of producing an important part of the . . . forage needs of local communities, and contributing to the protection of watersheds, thereby alleviating flood damage and insuring a continuing water supply, increasing opportunity for local employment, bringing greater stability to local communities, and increasing returns to counties in the national forests from their share of national forest receipts." Under this program the national forests of Utah, Nevada, and southwestern Wyoming, have treated large acreages of federally-owned land including sizeable areas in the sagebrush-grass and pinyon-juniper types.

The Granger-Thye Act of 1950 (USDA 1964) provided for cooperative rehabilitation of ranges adjacent to Forest Service lands. However, the program has not been popular, for various reasons. There are instances where the Forest Service has used Granger-Thye funds in cooperative seeding of State Fish and Game lands adjacent to the National Forest for the grazing of cattle permitted on the forest. Otherwise, there are few, if any, successful cooperative endeavors on privately-owned ranges under this program.

The Bureau of Land Management has received sizeable sums of money for range rehabilitation and has planned vigorous future programs. In Utah, BLM personnel have estimated that 1 1/2 million acres of BLM lands in the state are in need of reseeding (Keogh 1964). To date, approximately 200,000 acres have been seeded in Utah. Over twice that amount has been seeded in Nevada (Delano 1964). Exact figures were not obtained on the acreage of BLM lands needing reseeding in Nevada, but it may be as much as twice the acreage estimated for Utah.

Sizeable acreages of Indian tribal lands are being seeded in both Utah and Nevada. In Utah, the total acreage of tribal and trust lands administered by the BIA amounts to 2,370,956 acres (Roberts and Wennergren 1964). Much of this land and sizeable acreages in Nevada are in need of reseeding.

Private ranchers are taking greater advantage than they have in the past of federal cost-sharing programs for range seeding and improved management practices. Funds are made available through the Agricultural Stabilization and Conservation Service. Practices are approved by local county committees.

Maximum federal cost share ^{private} on range lands is 70 percent of the cost of seed for drilling, not to exceed \$4.00 per acre; 50 percent of the cost of seed for broadcasting, not to exceed \$4.00 per acre; \$2.50 per acre for plowing for brush removal; \$1.25 per acre for second plowing in control of rabbitbrush; \$1.00 per acre for drilling; \$0.30 per acre for broadcasting or airplane seeding; 50 percent of

the cost for control of competitive shrubs, not to exceed \$2.00 per acre for sagebrush, rabbitbrush and greasewood, and \$4.00 per acre for juniper; \$0.60, \$0.30, and \$0.15 per acre, respectively, for deferred grazing on summer, spring-fall, and winter ranges.

Additional approved practices include developing springs and seeps for livestock and wildlife water, installing pipelines, water storage, construction of permanent fences, etc. Lands owned by the state and leased by private operators come under the same program. Thus, there is considerable incentive for range rehabilitation and improvement by private operators.

Although the State Fish and Game department has not cooperated in rehabilitating private ranges, to date (March 1965) it has cooperated in rehabilitating some 28,225 acres of federally-owned range in Utah, including 22,607 acres of BLM land and 5,618 acres of FS lands with the stipulation that livestock grazing be withheld for 3 years (Davis 1965). Also, to date, some 23,760 acres of department-owned lands have been rehabilitated. The present ^{F+G} annual budget for rehabilitating range lands will treat about 4,500 acres. Indications are that land purchases and rehabilitation programs will go forward as rapidly as funds and other circumstances permit.

The objective of livestock reduction programs on federally-owned ranges has been to bring livestock numbers in harmony with carrying capacity of the range. Between 1940 and 1956, the number of cattle on the national forests of Utah decreased from 122,924 to 118,768--a reduction of only 3.4 percent (Iverson 1957). By 1963, the number had declined to 100,012 or 15.8 percent since 1956.

Reductions in numbers of permitted sheep have been greater than for cattle. The number of stock sheep on the national forests of Utah declined from 717,981 in 1940 to 489,759 in 1956--a reduction of 32.5 percent. However, during this period, stock sheep for the state as a whole declined from 2,095,000 in 1940 to 1,369,000 in 1956--a decline of 34.7 percent. By 1963, stock sheep on national forests of Utah had declined to 398,647--an 18.6 percent reduction since 1956 or 41.5 percent since 1940.

Conflicts Between Uses

Conflicts between uses of land create problems of management which often require solution by research. Increased demands for mining, recreation, water, wood products, and forage for domestic livestock and wildlife could produce conflicts between certain uses. Some conflicts would be greater than others. On the national forests it is expected that recreational facilities would involve relatively small acreages of land and that their use would conflict very little with forage and timber harvesting (Iverson 1957). Probably this principle is even more applicable to the lands encompassed by this project. It is expected also, that mining will involve relatively small acreages, which will not conflict seriously with other uses.

Although these low-elevation lands are not important water-producing areas, they are becoming increasingly important for water storage reservoirs along the Colorado, Green, and many lesser rivers and streams within the project territory. Even so, acreages involved

are relatively small and will conflict very little with grazing.

The water storage areas themselves, will greatly enhance recreational and scenic or aesthetic values of the area.

A very important overall consideration is the prevention of excessive runoff and accelerated soil erosion from lands encompassed by the project. Sediment from accelerated erosion can reduce the storage life and usefulness of reservoirs and cause great damage to cities, highways, agricultural lands, etc.

Inasmuch as juniper and pinyon trees occupy much land that would otherwise produce forage, there is possible conflict between uses for grazing and production of wood products. The rapid extension of juniper trees into sagebrush-grass lands is reducing the area available for grazing. This appears to be a major problem inasmuch as juniper trees at present have very little value compared to the values of these lands for grazing.

Major conflicts exist in certain localities between livestock and big-game animals, particularly between sheep and deer. Over the years since 1920, sheep numbers have greatly decreased, whereas deer numbers have greatly increased. Stockmen today, whose livestock numbers have been reduced on public-owned ranges, are concerned about the possible future increase in numbers of big-game animals on these ranges. Sportsmen, generally, want more big-game animals. In most areas of the state sportsmen and stockmen are appreciative of each other's problems and they are interested in reasonable solutions. Likewise, game and land managers are interested in reasonable solutions.

There are stockmen and others who think that purchase of private lands by the State Fish and Game department is unnecessary and that the money could be better spent in cooperative rehabilitation programs with private owners. Livestock owners contend that over the years big-game animals contributed heavily to the forage depletion on privately-owned spring-fall (deer winter) ranges and that cooperative rehabilitation programs are necessary and justified. Some people have objected to lands being taken off county tax rolls, but recently the Utah State Legislature passed a bill to reimburse counties with money "in lieu of taxes" amounting to what the taxes would have been if State Fish and Game-owned lands were still in private ownership. There are still some people who contend that a part of the receipts from the sale of hunting and fishing licenses should be returned to counties for support of schools, etc. as is done with receipts from the National Forests and Bureau of Land Management ranges.

In local areas stockmen contend that the "wholesale" destruction of tree cover on Fish and Game-owned lands, up to private property lines, has forced deer to continue to seek shelter and protection on adjacent privately-owned ranges which are also badly in need of rehabilitation. In severe winters it appears that good shelter and poor forage afforded by juniper trees is more important to deer than the poor shelter and better forage of the rehabilitated areas. Forest Service officials reported seeing thin and apparently starving deer in Millard county in untreated juniper stands within relatively short distances of large treated areas (Winkler 1965). Some officials

point to the reinvasion of treated areas by young trees and surmise that the situation described above is only temporary and that tree cover will eventually return on treated areas. These conditions, and others described elsewhere, indicate there are many problems yet to be solved.

Although sheepmen have outbid cattlemen for available grazing on Fish and Game lands, bids have been let only to cattlemen. Sheepmen are greatly concerned over this situation, particularly when they continue to support deer on their privately-owned lands.

The age-old conflict between sheep and cattle owners has not been completely solved. National Forest Administration has found it necessary to separate sheep and cattle grazing for effective range management. Some research has shown that common use by sheep and cattle is advantageous from the standpoint of efficient use of summer range (Cook 1954). There is little evidence, however, showing just how the two classes of stock can be effectively managed together for improvement of summer ranges.

No doubt the excessive numbers of sheep in earlier days contributed heavily to the early depletion of much range land (Dyrenge 1947). Sheepmen contend, however, that with good herders sheep are more easily managed and are less destructive to the range than cattle. In support of this idea, some research has shown that grasses tend to increase on sheep summer ranges (Ellison 1954); also, that grasses are much superior to forbs in preventing runoff and soil erosion (Meeuwig 1960).

The heavier reductions in sheep than cattle numbers on national forest ranges are probably due to economics of the industry. Also, there has probably been more shifting from sheep to cattle operations than the reverse. This is understandable on the basis of economics involved in maintaining a camp and herders with sheep, whereas this is not required with cattle. When sheep numbers are reduced below an economic unit, owners are forced to liquidate or change their type of operation. In some instances, at least, the change has been to cattle.

Both sheep and cattle owners contend that the higher summer ranges put a "bloom" on livestock in late summer that is not possible on low-elevation range. For this reason they support programs to rehabilitate and use low elevation ranges in early summer and fall, reserving higher ranges for use in the critical late summer period. Where stockmen have ample spring-fall range, they usually prefer reductions in season of use on summer and winter ranges rather than in numbers of animals.

It has been demonstrated at Dubois, Idaho that sheep grazing can be an effective management "tool" for improving sagebrush-grass spring-fall ranges (Laycock 1961). Grass increased and sagebrush decreased under fall grazing by sheep on native range. Similar results have been obtained recently on crested wheatgrass range at Benmore, Utah.

It has been demonstrated also that sheep can make efficient use of salt-desert shrub ranges (Hutchings and Stewart 1953). Probably cattle are much less efficient than sheep in use of salt-desert

shrub ranges. This is borne out by the numbers of sheep and cattle on BLM ranges in Utah. A total of 1,050,063 sheep graze these ranges compared to 157,128 cattle. By way of comparison 398,647 sheep are permitted on the national forests of Utah compared to 100,012 head of cattle.

Aside from reductions in livestock numbers, both the Forest Service and the Bureau of Land Management have made extensive reductions in length of summer and winter grazing seasons on lands they administer. Shortened seasons on public summer and winter ranges means longer seasons on private spring-fall ranges. Thus, there is dire need for integrating use of publicly-owned spring-fall ranges with privately-owned spring-fall ranges and these in turn with summer and winter ranges, if these ranges as a whole are to achieve their full potential.

Probable Future Developments

The increased population, plus changes in food preferences resulting from a higher standard of living, will place increased demand for livestock products as opposed to crop products such as cereals and potatoes (Utah State University 1960). It has been estimated that 58 percent more beef and veal would be required nationally by 1975 to satisfy consumer demands (Reiman 1959). The figure will be higher than this for the western states where population increases will be greatest. Likewise, there will be increased demands for lamb, mutton, and wool. More and better forages will

be needed to meet the increased demand for meat and livestock products. Present trends suggest that some crop lands should be shifted from production of wheat and other crops to grasslands and other forages for livestock. Aside from reseeding depleted lands, increased production of all range lands through improved management practices will be a major goal.

Policies of the Bureau of Land Management and the U.S. Forest Service will have tremendous influence either directly or indirectly upon use of most rangelands in Nevada and Utah where 87 percent and 71 percent of the total land area, respectively, are federally owned. Indications are that grazing of livestock will continue to be an important use of federally-owned lands (Iverson 1957) (Fulcher 1964). Endeavors by these agencies to bring stocking levels in line with grazing capacities ^{will help} ~~has been done~~ to insure stable future operations. No doubt, reductions in permitted livestock numbers will continue to be made where needed. Restoration of some reductions may be possible in certain areas as ranges improve, particularly in connection with revegetation programs. An important consideration so far as this project is concerned is not only improved spring-fall grazing, but the possibility for extended grazing on these low-elevation lands into summer. Such practice could enable these lands to absorb reductions in livestock numbers from the higher watershed lands, and also provide for additional numbers of livestock and big-game in many areas.

Fortunately, the sagebrush-grass and pinyon-juniper types encompass sizeable areas that are suitable for artificial seeding. This practice can stabilize soils and increase quantity and quality of forage in a minimum of time. Already, probably upwards of 2 million acres in these types have been seeded by the various agencies and private operators. This is only a fraction of the land that could be seeded. Probably between 5 and 10 million additional acres in the sagebrush-grass and pinyon-juniper types could be profitably seeded to adapted species such as the widely-used crested wheatgrass. In addition to direct benefits from increased carrying capacity on seeded areas, indirect benefits would include improvement of adjacent native ranges as livestock are removed from these lands to seeded areas. Further benefits could be derived by developing management practices to maintain both seeded and native ranges at maximum productivity. This would involve integrating use of seeded and native ranges at different periods of the year and possibly by different classes of livestock. Under present conditions, the increasing population^{also} will create greater demand for big-game animals for which range will be needed.

Position of Resource as Result of Problem Solution

The successful seeding of 5 million acres of seriously depleted rangelands could amount to 2 million additional cow months of grazing. Considering returns of 40 pounds of beef per acre, which has been achieved at Benmore, at 20 cents per pound, the additional grazing would be worth \$40 million annually. This figure could be increased by developing ways of grazing cattle and sheep in combination so that sheep could utilize and thus control invading brush in seeded grass stands.

Increased grazing capacity on seeded range would lighten use on adjacent native range. Through improved management practices based on research, grazing capacity could probably be doubled on several million acres of native range. With these improvements and proper integration of use between vegetation types, seeded and native range, and classes of livestock, it is possible that increases of around \$100 million annually might be expected in livestock returns from lands within the project area. In addition, the range rehabilitation and improved management programs would contribute greatly to increased forage for big game.

RESEARCH PROBLEMS

Conflicts in uses of ranges give rise to research problems. Better understanding of basic principles is needed as a basis for permanent management. Testing of pertinent theories is desirable and necessary. In this analysis, research problems will be discussed according to the three main vegetative types; i.e. pinyon-juniper, sagebrush-grass, and salt-desert-shrub.

Pinyon-Juniper Type

Previous Analyses

In previous problem analyses, Hutchings and McGinnies (1949) listed the following to be important research problems in the pinyon-juniper type: (1) Values of present tree stands in relation to values for forage; (2) Effects of grazing on juniper invasion; (3) Role of fire in restricting juniper; (4) Management of present ranges to control tree invasion; and (5) Management of ranges following improvement. Blaisdell (1953) considered the increase of tree density and their invasion of adjacent areas to be of sufficient importance that they should receive high priority for study. Two suggested problems for study were: (1) Conditions which encourage spread of juniper, and (2) Management practices which minimize spread.

Ellison (1949) combined ideas from several problem analyses by range research personnel, including those of Hutchings and McGinnies. He concluded that certain kinds of problems extended across most rangelands of the Intermountain region and grouped them

under four broad headings as follows: (1) ecological basis for management; (2) criteria for judging condition and trend; (3) influence of animals on the range complex; and (4) control of undesirable plants. He concluded that a discussion of controlling juniper invasion was premature at that time because of lack of research on ecology of the pinyon-juniper type.

Current Problems

Research problems in the pinyon-juniper type might be grouped under two major headings: (1) site evaluation, and (2) type conversion. An outline of problems would be as follows:

1. Site evaluation

a. Site potential

(1) For tree products

(2) For forage

b. Establishment of condition classes (Range condition concept versus seral stages of succession)

c. Criteria for judging condition and trend

2. Management requirements

(1) Unimproved ranges

(2) Improved ranges

2. Type conversion

a. Methods

(1) Mechanical

(2) Growth regulators (chemical)

(3) Fire

(4) Biological control

b. Cover requirements for big game ✓ W1

c. Requirements for soil protection ✓

d. Factors influencing spread of trees

(1) Life history studies of trees (Frequency of seed crops, seed distribution, seedling establishment, growth rates, longevity, etc.)

(2) Role of competing vegetation

(a) Life history studies of important species.

(3) Role of grazing

(4) Role of insects and diseases

(5) Role of fire

An alternative way of grouping problems would be according to the following functions: (1) ecological, including soils, (2) physiological, (3) taxonomic, (4) influences of range pests, and (5) tests of basic theories for developing management programs, including grazing of animals.

Basic ecological studies are needed on the distribution of tree populations in space and time, community structure, life histories, and interrelationships between plant behavior and habitat. Information is needed on the characteristics of vegetation and soil on relict pinyon-juniper sites to aid in evaluating present-day trends caused by grazing, fire, tree cutting, and other factors. Facts are needed on rate of tree spread on ranges in various condition classes and under various treatments as a basis for systems of management.

Physiological studies are needed on the growth requirements of trees and the effects of grazing, fire, and other damaging agents. Physiological studies are needed also on factors influencing palatability of trees and why some are grazed heavily and others little. Studies of plant inhibitors are needed pertaining to trees, shrubs and herbaceous species. Information is needed also on effective ways of reducing water loss in the pinyon-juniper type, both from plants and soil.

Taxonomic studies are needed to identify natural plant races, varieties, or strains within species, particularly as they influence tree spread and adaptability to common environmental factors.

Influences of tree pests such as insects and pathogens should be studied. This should include study of factors influencing fluctuations of populations, particularly with reference to range conditions. This information might lead to developing effective biological controls.

Grazing and other studies are needed to evaluate possibilities for common use by deer and livestock, particularly sheep, in the pinyon-juniper type. Such studies also lend themselves to development of criteria for judging condition, trend, and proper utilization of forage species. Studies involving big game should be cooperative with Project 1803.

Past and **Present** Research on Pinyon-Juniper

Published information on pinyon-juniper in the Intermountain region is rather limited. Woodbury (1947) described the range of the pinyon-juniper forest in Utah and northeastern Arizona. Cottam and Stewart (1940) and Cottam (1947) indicated that the probable increase of the pinyon-juniper type in the Great Basin of Utah was from 10 percent of the area in 1847 to 38 percent in 1937, due largely to overgrazing of associated plants.

Plummer (1958) outlined problems associated with restoration of pinyon-juniper ranges including advantages and disadvantages of tree removal methods. Data from 10 sites in central and southwestern Utah showed about 8 times more production of understory vegetation where trees were removed than where not removed.

Thompson (1957) found that runoff and sediment loss from generally bare openings in the pinyon-juniper type was much greater than from any of 6 other depleted range types.

Woodward (1943) observed that water and soil losses were negligible in the pinyon-juniper type where plant cover was good in the Sevier River Basin.

Moessner (1962) developed preliminary aerial volume tables for pinyon-juniper stands, including a cubic-foot volume table, and a table giving the numbers of fenceposts per acre.

Parker (1945) and Reynolds (1959) listed important causes for increase of woody plants including juniper, in the Southwest to be: grazing by domestic livestock, drought, cessation of grassland fires, and natural biotic factors.

The Soil Conservation Service has obtained various measurements on juniper-pinyon trees in 7 different areas throughout Utah to evaluate tree growth with sites and range conditions. The 7 areas include Northern Utah, near Vernon in Tooele County, Juab County, Price river watershed, Sanpete, Beaver, and Kane counties. Soil Conservation Service personnel requested the assistance of Intermountain Forest and Range Experiment Station personnel to assist in evaluating the data. Some preliminary evaluations have been made. Possibilities for further cooperation with the SCS in this field appear excellent.

The U.S. Forest Service, Region 4, has prepared a working tool "Juniper and Pinyon Pine Areas--Management Objectives for Coordinating Uses by Management Situations" (1963) for use in Region 4. Region 4 personnel are continuing development of condition standards for juniper range types, including soils. Also, Region 4 personnel have been following changes on photo transects in juniper-pinyon stands in Utah and Nevada since about 1943. There has been some question whether the region will continue followup on these and other photo-transects. If not, past information and photos could be a valuable addition to research files, should they become available.

Limited studies by Smith and Julander (1953) showed that fall and winter sheep grazing would conflict with winter use by deer on the same areas since both classes of animals tend to choose the same species. The probability of conflict on the spring range is less than at other times of the year since deer move up the mountain

considerably ahead of sheep.

The Game Forage Revegetation part of Project FS-INT-1803 headquartered at Ephraim, involves seven major fields of endeavor as follows: Species adaption; Recognition of suitable sites; Seed germination; Site preparation and planting; Protecting plantings from rodents, rabbits, birds, insects and other biotic factors; Formulating practical recommendations; and Species and cover changes on restored areas (Plummer, et al. 1963). This project is cooperative with the Utah State Fish and Game department. Opportunities appear good for one or more cooperative studies with Project 1803.

Utah State University is presently conducting a study sponsored by the Bureau of Land Management to help answer the question: "How can pinyon-juniper land be allocated among uses over time to maximize benefits accruing to the society of users and owners?"

Objectives are: (1) to develop ecological criteria for classification of juniper-pinyon sites and establish a basis for recognition of these sites, and (2) to assess the economic value of multiple products including present and estimated future market opportunities as well as important non-monetary values. Their first approach was to identify site quality classes and to correlate each with some index based on tree growth. Other criteria for determining site quality are integration of physiographic and climatic factors like soil depth, parent material, soil texture and profile development, rainfall with an estimate of P/E ratio, aspect, degree of slope, latitude, elevation, etc.

Research Plans

The study being conducted by the Utah State University should provide considerable information on site potential for tree products versus forage. Another important problem is to discover ways of controlling the rapid spread of young junipers. Studies in this category should receive high priority. A list of proposed studies under the five functions outlined earlier are given below. Priorities are listed as being high (H), medium (M), and low (L). High priority studies are proposed to begin within one year, medium within one to three years, and low within three to five years. Order of priority is assigned mainly on the basis of economic importance, opportunity to obtain fundamental knowledge for land use, and lack of information being provided by others. Other determining factors include availability of funds and facilities, opportunity for cooperation, etc.

Ecological Studies

- H Factors favoring invasion and reinvasion by juniper.
- M Evaluation of community structure in the pinyon-juniper type and distribution of oplant populations.
- M Life history studies of important species
- M Evaluation of range condition concept with seral stages in plant succession.
- ✓M Criteria for determining pinyon-juniper areas to be converted to grass.
- ✓L Soil and plant indicators of range condition and trend.
- ✓L Cover requirements for soil stability in the pinyon-juniper type.

Physiological Studies

- M Effects of plant extracts on seed germination and growth of seedlings. ✓
- M Growth requirements of trees and physiological effects of grazing, fire, and other damaging agents.

Taxonomic Studies

- H Collection and identification of plants in the pinyon-juniper type.
- L Discernment of races or strains of trees having special qualities.

Influence of Range Pests

- M Effects of insects and pathogens on trees and associated plants.
- L Influence of soil micro-organisms on productivity of range sites.

Tests of Theories for Management Programs

- H Possibilities for joint use of improved pinyon-juniper ranges by deer and sheep (Cooperative with Project 1803).
- H The role of fire as a management tool in the pinyon-juniper type.
- M Requirements for managing pinyon-juniper range in different condition classes and integration of use with other range types.
- M Requirements for big-game cover in tree removal programs (Cooperative with Project 1803).
- L Effects of trees upon livestock grazing habits and weight gains at different seasons.

Living quarters and other facilities at Benmore can be used to advantage for conducting some of the studies. The 4,400-acre Dutch unit south of the present experimental pastures provides one area for research on factors influencing spread of juniper. In this unit various sagebrush control treatments have been applied on sizeable areas. Young junipers are invading. The native grass stand on much of the area, together with existing brush, appears adequate to carry fire. Remnants of an older stand of trees are present about 4 miles west of Benmore headquarters. Remaining trees are approximately 20 feet high and about $2\frac{1}{2}$ feet in diameter. Ring counts from an old stump showed ages to be in the neighborhood of 350 years.

Studies can be initiated as fast as money and manpower become available. Studies listed as having high priority can be initiated as soon as study plans are approved. It is anticipated that one or two graduate students would be assigned to phases of these studies. Until we have facilities of our own, limited greenhouse space and laboratory facilities are available at Brigham Young University for use by graduate students. Certain studies would be cooperative with Project 1803, as indicated.

Sagebrush-Grass Type

Previous Analyses

Hutchings and McGinnies (1949) considered research on the rehabilitation and management of the sagebrush-grass type in northern Nevada to be of high priority.

In 1953, Blaisdell considered the overall problems on spring-fall range of the Intermountain region to be: (1) how to maintain these ranges in productive condition; and (2) how to restore depleted range on which present vegetation differs from the original.

Holmgren (1960) suggests that the use of fire should be investigated on brush ranges, both as a management tool and as a damaging agent.

Past Work

The Intermountain Forest and Range Experiment Station has pioneered much range research in the sagebrush-grass type as well as in other vegetation types of the Intermountain west. Research in the sagebrush-grass types began at the U.S. Sheep Station at Dubois, Idaho in the early 1920's. Research in the 1930's, there and elsewhere in the states of Utah, Idaho, and Nevada, demonstrated the feasibility of quickly restoring herbage production by killing brush and seeding adapted grasses. Grazing studies on seeded crested wheatgrass range were started near Vernon, Utah at the Benmore Experimental Area in 1942; at Ruby Valley, Nevada in 1944; and at Ephraim, Utah in 1945.

Numerous publications have been prepared dealing with brush eradication and seeding of depleted ranges. Much less is known about management of native sagebrush-grass ranges within the project area although considerable information has been published from research at Dubois, Idaho. Much of the sagebrush-grass type encompassed by this project has been so vastly depleted that most research emphasis has been on range reseeding and management of seeded stands.

Comprehensive studies on grazing management of fairway and crested wheatgrasses at Benmore show that spring utilization of more than 60 percent of the current year's herbage decreased forage production and encouraged sagebrush reinvasion, which reduced grass yields. Even with light grazing, and where there was no grazing, sagebrush invaded good grass stands in 2 out of 10 years when moisture was especially favorable (Frischknecht and Harris ____). Subsequent investigation showed that big sagebrush was a much more serious threat than rubber rabbitbrush to productivity of crested wheatgrass (Frischknecht 1963).

Studies at Ruby Valley, Nevada, showed that amount of sagebrush present initially and intensity of grazing were important factors in sagebrush invasion of crested wheatgrass range (Frischknecht and Bleak 1957).

Studies with sheep at Ephraim show that intensity of grazing affected decline of crested wheatgrass (Bleak and Plummer 1953), but that yields of bulbous bluegrass were influenced more by weather than intensity of grazing (Plummer ____).

Considerable information has been published on the presettlement vegetation of the sagebrush-grass type (Cottam and Stewart 1940), (Cottam 1947), (Christensen and Johnson 1964), (Christensen and Welsh 1963), (Mason 1963), Passey and Hugie 1962).

Much less is known about requirements for managing these ranges in different condition classes.

Current Studies

Since establishment of this project, five main studies have been in progress--all on crested wheatgrass range. Titles and objectives are as follows:

FS-INT-1703-(B-1) Productivity of crested wheatgrass, gain in sheep weight and changes in plant cover in relation to intensity of grazing use.

Objectives: The main objectives are outline in the title.

FS-INT-1703-(B-2) Effect of season of grazing and supplemental feeding on cattle performance and on response of crested wheatgrass range.

- Objectives:
1. To determine how grazing during different seasons affects utilization and production of crested and fairway wheatgrasses.
 2. To determine the extent to which cattle gains on crested and fairway wheatgrasses are influenced by season of grazing.
 3. To determine if a protein supplement fed to cattle on crested and fairway wheatgrass range during the summer and fall improves grass utilization and increases carrying capacity and animal gains.
 4. To obtain background information for subsequent development of efficient systems of grazing crested wheatgrass range, including its use in conjunction with native spring-fall and summer ranges.

FS-INT-1703-(B-3) Effect of various periods of protection upon productivity of crested wheatgrass.

- Objectives:
1. To compare productivity of crested wheatgrass under total protection from livestock grazing with productivity of surrounding grazed range.
 2. To determine whether productivity under protection is influenced by the accumulation of old growth.
 3. To determine whether length of protection and age of stand affects productivity.

FS-INT-1703-(B-4) Ecological relationship of big sagebrush and rubber rabbitbrush with crested and fairway wheatgrasses.

- Objectives:
1. To determine how big sagebrush and rubber rabbitbrush affect grass yields.
 2. To determine factors responsible for invasion of big sagebrush and rubber rabbitbrush into seeded stands of crested and fairway wheatgrasses.

FS-INT-1703-(B-5) Management practices to control brush invasion on crested wheatgrass range.

- Objectives:
1. To investigate possibilities for controlling big sagebrush and rubber rabbitbrush on crested wheatgrass range by fall sheep grazing.
 2. To determine how size and amount of brush influences utilization of the shrubs by sheep.

Study B-1 was terminated in 1964 and a final report in the form of a journal article is nearing completion. Studies B-2 and B-3 will be terminated this year (1965), and results will be summarized for publication in journal articles. Study B-5 will either be terminated or revised this year (1965), and these data will be prepared for publication. Study B-4 is in a "standby" status. Data from this study are being considered as possible material for inclusion in a Ph.D. dissertation at Brigham Young University.

Current Research by Other Agencies and Institutions

A Cooperative Western Regional Project (W-25) among eleven western states and Hawaii experiment stations has as its broad title "Ecology and improvement of brush-infested ranges". Cooperating federal agencies include the Agricultural Research Service, Forest Service, Soil Conservation Service, and the Bureau of Land Management. The states of Idaho, Oregon, and Washington are cooperating on a tri-state project--"Development of a fundamental vegetation; soils classification of non-forested ranges as a basis for range improvement and management." The Nevada experiment station has been studying "Management of crested wheatgrass range pastures to delay encroachment by undesirable brush." The Utah experiment station (USU) has been studying "Plant and soil relationships determining changes in plant cover on desert-shrub lands."

The Utah Experiment Station has underway studies on livestock responses from seeded and native foothill ranges, and use of fertilizers and herbicides in maintaining productivity. In addition to studies on crested wheatgrass already mentioned, the Nevada Experiment Station has initiated studies of plant communities in the Northern Desert-Shrub zone. Agricultural Research Service personnel in Utah and Nevada have studies underway on various phases of artificial revegetation.

Current Problems

Problems for research in the sagebrush-grass type can be grouped according to the five functions outlined for the pinyon-juniper type.

Basic ecological studies are needed on the distribution of plant populations in space and time, community structure, life history of the main brush, grass, and forb species, and interrelationships between plant behavior and habitat. Facts are needed on rate of change on ranges in various condition classes under various treatments as a basis for systems of management.

Physiological studies are needed on the growth requirements of the main forage species and the effects of herbage removal at different seasons of the year. This will provide basic information for improving forage quantity and quality through grazing management. Physiological studies are needed also on factors influencing palatability and why some plants are grazed heavily and others little, which is a major cause of range deterioration. Information is needed on effective ways of reducing water loss from plants and soils so that a maximum of green forage is available in spring, summer, and fall.

Taxonomic studies are needed to identify natural plant races, varieties, or strains within species, particularly as they influence palatability, nutritive value, tolerance to grazing and other environmental factors including susceptibility to diseases and insects. Such knowledge will lead to developing superior plants through selection and breeding.

Influences of range pests such as small mammals, insects, and pathogens should be studied. This should include study of factors influencing fluctuations of populations, particularly with reference to range condition. This information would aid in establishing the need for, and the development of, effective controls.

Grazing and related studies are needed to determine the potential of native sagebrush-grass ranges within this project and requirements for managing ranges below the potential. Such investigation should be correlated with studies of seeded range. Research should answer the question posed by range managers: "What is the grazing capacity of spring-fall range at different seasons of the year, and how should it be used in connection with seeded range?" To determine this, a seasonal grazing study is warranted, similar to the current study (B-2) on crested wheatgrass. Information from the two studies would provide recommendations for management.

Information from study B-2 indicates that grazing crested wheatgrass for only 30 days in early spring (April 20 - May 20) allows regrowth of grass that remains greener and more succulent throughout the summer than grass that has not been grazed in the spring. A new study should be inaugurated to determine possibilities for two-season grazing on crested wheatgrass for maximum livestock returns and for maintaining livestock weights in summer and fall. Since some treatments will likely be rather severe on the grass, the development and testing of rest-rotation grazing also would be involved.

Research Plans

Proposed studies and priorities are listed below. Priorities are listed in parenthesis: (H) to begin within one year, (M) to begin within one to three years, and (L) to begin within three to five years.

Ecological Studies

- M Life history studies of important species.
- M Soil and plant indicators of range condition and trend.
- M Evaluation of range condition concept with seral stages in plant succession.
- M Cover requirements for soil stability on seeded range.
- L Evaluation of community structure and distribution of plant populations.

Physiological Studies

- M Factors influencing palatability of plants.
- M Effects of herbage removal at different seasons on subsequent plant growth and development.
- L Effects of plant extracts on seed germination and growth of seedlings.

Taxonomic Studies

- H Collection and identification of plants in the sagebrush-grass types.
- L Discernment of races or strains within plant species with particular reference to palatability, nutritive value, tolerance to grazing, soil protection, etc.

Influence of Range Pests

- M Effects of insects on important plants.
- M Effects of small mammals on soils and vegetation.
- M A survey of diseases of range plants and their importance.
- L Factors influencing fluctuations in small mammal populations with particular reference to range condition.
- L Influence of soil micro-organisms on productivity of range sites.

Tests of Theories for Management Programs

- H Effects of early spring grazing of crested wheatgrass in maintaining high nutritive quality for extending grazing into summer and fall (Cooperative with Utah State University).
- H Requirements for managing native sagebrush-grass ranges in different condition classes at different seasons of grazing by cattle. (Cooperative with Utah State University)
- M The role of fire as a management tool on native sagebrush-grass range.
- M The role of fire as a management tool for controlling brush on seeded range.
- L Effects of livestock trampling on vegetation on different sites and at different seasons.

It would be advantageous to conduct the two grazing studies at Benmore listed as having high priority/because of existing facilities and good cooperative relations. An additional factor favoring the Benmore location for the study on native range is that different brush control treatments have been applied to sizeable areas in the Dutch unit which now represent different conditions of sagebrush-grass range.

By way of history, grazing of the experimental crested wheatgrass pastures eliminated spring use in the 4,200-acre Dutch unit and permitted recovery of native sagebrush-grass vegetation. While in depleted condition (1945-47) daily cattle gains on the Dutch unit were little more than half those on the seeded range, and the stocking rate was only about one-tenth as heavy, making the advantage about 20 to 1 in favor of seeded range. At that time, grass on the native range averaged approximately 80 pounds per acre (air-dry), of which 32 percent was considered unavailable to cattle because of the mechanical obstruction of big sagebrush. Under 15 years of protection from spring grazing, grasses made tremendous recovery and much of this area could now be considered as good-condition native range.

Certain other studies such as those involving fire could also be studied at Benmore.

Salt-Desert-Shrub Type

Previous Analyses

Hutchings and McGinnies (1949) proposed several problems for research in the salt-desert shrub or closely related types as follows: (1) Management and rehabilitation of the salt-desert-shrub type for cattle, (2) Methods for rehabilitating black sagebrush (A. nova) ranges. . . , (3) Increasing forage production of blackbrush (Coleogyne ramosissima) ranges . . . , (4) A study of semi-annual migrations of livestock to and from winter ranges . . . , and (5) Mineral deficiencies and nutritional quality of forage on winter range. . . , (6) Methods of management and control of halogeton, and (7) Relation of rodents to range--forage production, forage use, etc.

Past Work

An outline by subject matter of past and current research by the Intermountain Forest and Range Experiment Station in the salt-desert-shrub type was prepared by Ralph C. Holmgren in the fall of 1964. It is reproduced here in its entirety as background material for proposed future studies.

Studies completed. (Most of this work has been published in more or less detail between 1936 and 1960.)

A. Vegetation sampling and statistical methods.

The need for an efficient method of quantitative sampling of vegetation resulted in the development of the point-observation plot (Stewart and Hutchings 1936). This technique of evaluating plant cover together with its modification for determining plant

yield (the weight-estimate method of Pechanec and Pickford 1937), have been and are still being used to survey vegetation on experimental winter range units, pastures and plots.

Stewart (op. cit., and with Keller 1936) was an early advocate of quantitative expression in range and ecological description, and he emphasized to ecologists the value and importance of statistical analyses for reliability of interpretation of data. Much of his teaching was founded on work done at the Desert Experimental Range and on similar sites elsewhere in the Intermountain States.

Other sampling techniques have been tested in salt-desert types, which because of their comparative simplicity, are ideal for making reliability checks. Only two of these tests have been reported: one on the bias of the loop-density index (Hutchings and Holmgren 1959); and one on the importance of degree of dispersion of plants in the results of distance-measure methods of sampling for density (Hutchings and Morris 1959).

B. Effect of unrestricted grazing on desert plant associations.

This classic study (Stewart, Cottam, and Hutchings 1940) was done in the early 1930's. It was a large-scale but intensive survey of the influence of overgrazing in two large valleys of western Utah. The major plant communities and the soils on which they were found were described, and the detrimental effect of overgrazing on plant composition and yield, and on soil stability,

were convincingly presented. The fact that one valley had a longer history of abuse than the other lent conviction to the authors' conclusions about the nature of retrogressional cover changes.

C. Range rehabilitation by artificial revegetation.

Several species, native and exotic, have been tested for adaptability for seeding in the arid salt-desert types, but none have shown promise enough to warrant recommendations for large-scale seedings (Plummer et al. 1955) (Bleak et al. 1965).

D. Soil-vegetation relations--root systems.

As part of the rather broad survey of overgrazing effects mentioned under B, above, laboratory analyses were made of soils from several plant associations. Root systems of the most important perennial species were charted and described. Big sagebrush, spiny hopsage, and the grasses rooted in soils or soil layers having a salt content of less than 1,000 p.p.m. Shadscale, little rabbitbrush, and winterfat roots penetrated into soils of greater salinity. Soil salinity increased with depth, and the depth at which salinity exceeds 1,000 p.p.m. varies among plant communities.

The influence of topography and geomorphology on distribution of plant communities was briefly noted in this study.

E. Phenology--Plant Development.

Growth periods, times of flowering, seed formation and dissemination, and plant dormancy were recorded for important

plant species at the Desert Experimental Range during the middle 1930's. These data have not been published in detail, but some of the findings are included in discussions of species in U.S. Department of Agriculture Farmers' Bulletin 2067 (Hutchings 1954).

F. Plant growth related to available moisture.

Herbage yield at the Desert Experimental Range is closely correlated with precipitation during the October 1 to September 30 water-year (Hutchings and Stewart 1953). Using a regression equation, it is possible to predict with reasonable confidence the herbage yield for winter forage use after the close of the water-year (Hutchings 1950, 1951). Annual grazing plans for the Desert Experimental Range are based on production estimates by this method, with minor adjustments made in stocking rates as needed during the grazing periods.

G. Palatability of plants--Periodic trends in utilization by sheep--Proper use factors.

Palatability of plants to sheep in winter varies with growing conditions of the previous season, and for some, it changes as the winter progresses. Degree of utilization depends also on relative abundance of plant species and intensity of stocking (Hutchings and Stewart 1953).

Observations of relative palatability and response of plants to different intensities of use at the Desert Experimental Range have resulted in recommendations for optimum degree of utilization of several important species on winter ranges of the Intermountain area (Hutchings 1938, and 1954).

H. Effect of season of use on plants and plant communities.

Under moderate grazing desirable forage species remain vigorous and productive when grazed only during the early and middle winter periods of plant dormancy. Grazing year after year during the late winter reduces production of species whose growth period is primarily very early spring: bud sagebrush, hopsage, ricegrass, squirreltail (Hutchings and Stewart 1953, Hutchings 1954). This study is continuing (See Studies in progress, A, 1, a and b below).

I. Effect of intensity of use on plants and plant communities.

Three intensities of grazing by sheep have been applied in the large range pastures at the Desert Experimental Range since 1934. Response of vegetation under the two lighter rates has been about the same, but different from the response under the heaviest rate (an average of about 1.8 acres per sheep per month). In the shadscale-winterfat types, there has been a tendency toward greater total production under the two lighter intensities than under the heavy, and the importance of winterfat in the total cover has become greater. Ricegrass recovery after drought also appeared to be more rapid under the lower stocking rates (Hutchings and Stewart 1953). This study is continuing (see Studies in progress, A 1, a, below).

J. Effect of intensity of use on sheep.

Sheep on moderately stocked range areas made better gains during the winter than sheep under light grazing. Sheep on heavily stocked ranges failed to make any gains. Wool production (shorn fleece weight) was about 1 pound less per head, lamb crops about 10 percent lower, and death losses about twice as high for sheep wintering on heavily grazed range than for sheep on moderately stocked range (Hutchings and Stewart 1953).

K. Stock water on winter range.

Sheep do better and drink less with water available every day than with less frequent waterings. The range is not damaged if water is brought to the sheep instead of having the sheep trail to the few isolated and widely dispersed watering places on the desert winter ranges. This was demonstrated at the Desert Experimental Range (Hutchings 1946, Hutchings and Stewart 1953, Hutchings 1954, 1958), and the recommendation that water be hauled to the grazing area has become an almost universally accepted practice of those who winter livestock on these ranges.

L. Economic aspects of winter range condition and grazing management practices.

Studies at the Desert Experimental Range (Hutchings and Stewart 1953, Hutchings 1954) have shown that good sheep winter range management pays off in several ways: the ewes remain in better flesh, lamb crops are larger, wool production is higher, death losses are fewer, and supplemental feed requirements are lower. Calculations based on a 3000-ewe operation at 1935-1943

costs and prices showed net income to be about twice as much from a herd wintered on moderately grazed range as from one on heavily grazed range.

Studies in progress

Since establishment of this project, six studies have been underway in the salt-desert-shrub type. Titles and objectives are given below. Early results from some of these studies have been published.

FS-INT-1703-(D-1) Effect of intensity and time of winter grazing on salt-desert vegetation.

Objectives: 1. To compare longtime effects of different intensities and periods of winter sheep grazing on herbage yields and plant-cover composition in order to develop grazing practices conducive to the improvement, and maintenance at maximum levels, of best-quality salt-desert-range forage.

FS-INT-1703-(D-2) Relation of halogeton invasion to condition of salt-desert range.

Objectives: 1. To follow the natural spread of halogeton on salt-desert range, and relate its success of occupancy of specific sites to cover condition.

FS-INT-1703-(D-3) Movement and dissipation of soil moisture under salt-desert shrub vegetation.

Objectives: 1. To follow soil moisture dissipation from desert soils under natural, bare, and plastic-covered surface conditions.

2. To observe field moisture conditions and percentages related to the available moisture range from 1/3 and 15 atmospheres, and to see if these are in agreement with the accepted "rules" of soil moisture relationships of "typical" soils.

3. To correlate moisture relations of field plots with laboratory analyses on these soils and compare results with others in relation to the "typical" pattern.

FS-INT-1703-(D-4) To determine trends in semi-desert vegetation in livestock and rabbit exclosures and on grazed range.

- Objectives:
1. To learn of the ecological recovery succession on some of the major range types of Nevada.
 2. To determine the potential vegetal composition and forage productivity of these sites.

FS-INT-1703-(D-5) Effect of the 1958-61 drought on some range plant communities of valleys in the western Great Basin.

- Objectives:
1. To obtain information on mortality and condition of perennial plants in various range types in west-central Nevada at the end of the 1958-1961 drought.

FS-INT-1703-(D-6) An ecological life history of Artemisia spinescens D.C. Eaton in Western Utah.

- Objectives:
1. To study the phenology, root systems, seed germination, longevity, and influence of physical site factors on bud sagebrush.
 2. To study effects of different grazing intensities and seasons of grazing by sheep on bud sagebrush.

* * * * *

A. Long-term trends in vegetation--Compositional changes.

1. Effects of grazing (Study D-1) primarily; also Studies D-4 and D-6.
 - a. Season and intensity of grazing--Range pastures, Desert Experimental Range.

Results from the early years of this study (mentioned in H and I, page 45) have been reported. Since the publication of Hutchings and Stewart (1953) there have been further changes in plant community makeup on the 20 large range pastures at the Desert Experimental Range. Additionally, there are obvious differences in individual plant vigor related to grazing treatment. The grazing

treatments have now been applied annually for 30 years, but the pasture vegetation has been inventoried only twice (in 1957 and 1958) since termination of annual sampling in 1947.

b. Season of grazing--Large grazing units, Desert Experimental Range.

Vegetation of the 13 large grazing units outside the pastures (11 for sheep, 2 for cattle) has never been sampled intensively, but a detailed type map of the whole area of the Desert Experimental Range and some adjacent sections of the Old Public Domain was prepared in 1935. Observations of livestock utilization of plants have been made in most years since 1935, and presence or frequency data from these records can be useful in showing compositional change after three decades of the various seasonal grazing treatments that have been applied on the several units. The intensity of use on all units has approximated the moderate rate of the range pastures. The seasons of use and grazing systems (same season, year after year; alternation of two seasons every other year; rest in alternate years) on the various units are shown on page 5 of U.S.D.A. Cir. 925 (Hutchings and Stewart 1953).

2. Potential of range sites, Nevada and western Utah (Studies D-1, D-4).

a. Secondary successional changes on ungrazed areas.

During the period 1932-1938, a total of seventy-eight 4-acre or 1-acre plots in west central Utah and central and northern Nevada were fenced to exclude livestock. The vegetation inside the exclosures (and on a similar site near each one) was sampled by estimating, by species, the plant cover and current year's weight yield. Counts were made of individual plants of the dominant perennial species on the same permanently-marked sampling units. In addition, plants on 100-square-foot quadrats were mapped by a modification of the technique of Pickford and Stewart (1935). Subsequent observations of the same nature have been made at irregular intervals since the initial sampling at most locations. A few of these studies in Nevada have been lost to fire, vandalism, or other land uses, but except for just one, not before their being resampled after a period of several years of protection. A great variety of ecological situations or range sites is represented by this series of plots. Soil profiles have been described for 22 of the areas in Nevada, and data covering 20 to 23 years of vegetational change (or lack of change) at these locations are in the process of analysis by electronic computer.

- b. Approximation of potential (qualitative and quantitative) productivity under grazing use.

The series of fenced exclosures described immediately above provide a comparison between effects of protection and grazing use. The type of grazing (season and animal class) is known approximately for 35 of the areas in Utah and Nevada. In addition to grazing type, the stocking rate for the past 30 years is also known for the other 42 areas, all of which are on the Desert Experimental Range. In some instances it appears that grazed native vegetation undergoes the same successional processes as protected range, but at a different rate. The Nevada grazed plots are currently being compared with their protected counterparts in the electronic computer program mentioned under "a" above.

B. Environmental factors other than livestock (Studies D-4, D-5, D-6).

1. Soils.

Soil profile descriptions and results of laboratory analyses are available for 22 study sites in Nevada to aid in characterizing those sites and correlating potential productivity with the soils factor. In a study of bud sagebrush (see "C" below), the soils of the various plant communities in which this species grows are being described.

2. Insects.

An important adjunct of the bud sagebrush study is to learn what insects infest this species and their importance in its survival and growth.

3. Small mammals (rodents and lagomorphs).

The effect of some small mammals on the vegetation can be separated from livestock grazing effects by the design of the experimental setup at 14 of the Nevada study areas mentioned under A, 2, a, (page 50) above. At each of these locations there is a 1/7-acre area from which all small mammals except the smaller mice have been excluded.

Trapping has been done at various times and places in Nevada and at the Desert Experimental Range, and records are on file of the various species caught. In addition, animal remains have been collected from fencelines at study areas where predatory birds have fed, and these remains have been identified.

Rodent influences are also of concern in the study of bud sagebrush.

4. Climate

a. Temperature.

Only a limited amount of work on the importance of temperature as an environmental factor has been done in the Desert-Range segment of Project 1703. However, there is a nearly-complete record of daily maximum and minimum air temperatures since 1934 for the Headquarters of the Desert Experimental Range. These observations are continuing, and are published in "Climatological Data"

(U.S. Dept. of Commerce, Weather Bureau).

At various times in the past, and currently as a phase of the bud sagebrush study, soil temperatures at one or more depths have been recorded.

b. Precipitation.

Precipitation records have been maintained at the Desert Experimental Range Headquarters for 31 years, and are continuing to be kept. They are published in "Climatological Data" (U.S. Dept. of Commerce, Weather Bureau). These data have been used to correlate plant production with precipitation (Hutchings and Stewart 1953). (See F, page 44)

In the bud sagebrush study it has been observed that seasonal distribution of moisture controls the end of that plant's dormancy period, and hence influences its midwinter palatability.

During the past year a series of six precipitation storage gages and two recording gages have been installed at seven locations on and near the Desert Experimental Range. These are intended to give information on areal pattern of storms in the southeastern Great Basin area, and the amount and seasonal distribution of precipitation as influenced by elevation and topography. A plan and procedural instructions for this study are being prepared.

Its purpose is to provide more information on which to base further study of the influence of precipitation on plant growth (time and amount) and on the pattern of vegetation from valley bottom to mountain top.

C. Autecology of important plant species.

Only one autecological study (D-6) is currently in progress on the Desert range, an ecological life history study of bud sagebrush (Artemisia spinescens D.C. Eat.). It includes descriptions of various environments in which it is found (plant communities, soils, geomorphology, elevation, climate) in the Great Basin, its developmental history, the influence of biotic factors (including livestock) on its reproduction, growth, survival, etc., and other important aspects such as its taxonomic status, geographic range, branching and rooting habits, economic importance, and chemical and nutritional composition at various times. Results of two years' study are being summarized in a Master's thesis at Brigham Young University by Benjamin W. Wood.

D. Desert game animals--Antelope.

The Forest Service, Intermountain Forest and Range Experiment Station, is cooperating at the Desert Experimental Range in a study of antelope herd productivity and survival. Under consideration in this study are fawn production and survival as related to range condition; seasonal forage preferences of antelope and their selection of grazing areas as influenced by weather; water consumption; and mortality factors. Preliminary findings have been reported (Beale 1963a, 1963b, 1964).

Research by Others

There has been considerable study of vegetation communities in the salt-desert-shrub type such as the following: Kearney, et al. (1914), Billings (1949), Fautin (1946), Fireman and Hayward (1952), Gates et al. (1956), and Vest (1962).

Considerable research on nutrition of salt-desert-shrub ranges has been conducted by Utah State Experiment Station (Cook, et al. 1954), (Cook and Harris 1950), Harris et al. 1956), and Esplin, et al. 1937).

Current research includes the study by the Utah Agricultural Experiment Station mentioned earlier under the W-25 program and two studies by the Nevada Agricultural Experiment Station: Plant communities in Nevada, and Galleta production in Nevada (University of Nevada Progress Report 1965).

Current Problems and Research Plans

Physical facilities at the Desert Experimental Range and background information acquired over three decades are ideal for conducting research on problems of the salt-desert shrub ranges of Utah and Nevada. The future program should be two-phased: (1) reexamination and updating of present studies, including reorientation of some and conclusion of others; and (2) expansion of effort to problems beyond the scope of current studies.

1. Review and possible wind-up of current studies.

There should be a new and current evaluation of grazing treatments in the experimental pastures and allotments (sheep and cattle) and on selected areas of the surrounding BLM range. Field work in this phase should include jobs listed below:

- a. Preparation of a new type map to show gross vegetational changes since the original type map was prepared in 1934.
- b. Reinventory of cover and yield in the range pastures.
- c. Reinventory of cover in exclosures and adjacent grazed plots.

(A variety of grazing seasons and intensities are represented in association with exclosures in pastures, range units on the Experimental Range, and on BLM range. Grazing in some of the latter has been by both cattle and sheep.)

- d. Soil descriptions to aid in evaluation of changes that have occurred in vegetation as indicated by findings under the three headings immediately above.

2. Expansion of research in the salt-desert shrub ranges. (To be conducted mainly at or near the Desert Experimental Range, with some field work in similar types farther away.)

Research problems can largely be grouped into the five main categories used for the pinyon-juniper and sagebrush-grass types.

Basic ecological studies are needed for a better understanding of successional status and potential of range types. This would include the distribution of plant populations in space and time, community structure, life history of individual species, and inter-relationships between plant behavior and habitat.

Physiological studies are needed to supplement present information on the growth requirements of important forage species and the effects of herbage removal at different seasons of the year. This will provide additional basic information for improving forage quantity and quality through grazing management. Physiological studies are needed also on factors influencing palatability and why some plants are grazed heavily and others little, which is a major cause of range deterioration. Information is needed on effective ways of reducing water loss from plants and soils.

Taxonomic studies are needed to identify natural plant races, varieties, or strains within species, particularly as they influence palatability, nutritive value, tolerance to grazing and other environmental factors including susceptibility to diseases and insects. Such knowledge will lead to developing superior plants through selection and breeding. A review of taxonomic nomenclature is warranted for plants growing in this type.

Influences of range pests such as small mammals, insects, and pathogens should be studied. This should include study of factors influencing fluctuations of populations, particularly with reference to range condition. This information would aid in establishing the need for, and the development of, effective controls.

Grazing and other studies should be instituted on some parts of the Desert Experimental Range. These studies might involve a reversal of grazing intensities in the pastures, new rest or rotation systems, longer seasons of use (earlier in fall, later in spring), change in class of livestock using certain areas, and integration of sheep and cattle use on the same areas. Such studies would contribute additional information for development of criteria for judging condition, trend, and proper utilization of forage species by different classes of animals. Effects upon animals should be included.

As stated elsewhere in the problem analysis, there is a need for better integration of all lands in the year-around forage provision for livestock. Some lands are not realizing their highest economic value because they are grazed by the wrong class of livestock or at the wrong time. A review of current uses could point up possible shifts in stocking that could alleviate heavy grazing pressures now known to exist on some seasonal ranges. Certainly the use of shrub range by cattle leaves unharvested much forage that is usable by sheep.

The costs of fencing, water developments, seeding, etc., should be weighed against the benefits and also the detriments they bring.

The effect of livestock grazing and of changes that are made by range improvement on native wildlife, which also have economic value, should be investigated. And the value of the wildlife themselves, is not well understood.

Proposed studies and priorities are listed below. Priorities are listed as high (H), to begin within 3 years; medium (M), to begin within 3 to 5 years; and low (L), to begin within 3 to 10 years.

Ecological Studies

- H Soil and plant indicators of range condition and trend, particularly as applied to land forms.
- H Environmental factors functioning in successional change.
- M Influence of range improvements such as water development and fencing on desert wildlife.
- M Life history studies of important species such as the present study on bud sagebrush.
- M Evaluation of range condition concept with seral stages in plant succession.
- M Correlation of annual-plant and perennial seedling establishment with weather.
- L Evaluation of community structure and distribution of plant populations

Physiological Studies

- H Factors influencing palatability of plants in the salt-desert-shrub type at different seasons.
- M Effects of herbage removal at different seasons on subsequent plant growth and development.
- L Effects of plant extracts on seed germination and growth of seedlings.

Taxonomic Studies

- H Collection and identification of plants in the salt-desert-shrub type.
- H Discernment of races or strains within plant species with particular reference to palatability, nutritive value, tolerance to grazing, soil protection, etc.

Influence of Range Pests

- M Effects of insects on important range plants.
- L Effects of small mammals on soils and vegetation.
- L Factors influencing fluctuations in small mammal populations with particular reference to range condition.
- L A survey of diseases of range plants and their importance.
- L Influence of soil micro-organisms on productivity of range sites.

Tests of Theories for Management Programs

- H Grazing systems for maintaining the highest production and nutritive quality of forage on salt-desert-shrub winter ranges for sheep.
- H Possibilities for extending grazing by sheep on salt-desert-shrub range into early fall and late spring--coordinated with use of sagebrush spring-fall ranges.
- M Grazing systems for maintaining the highest production and nutritive quality of forage on salt-desert-shrub ranges for cattle.
- M Requirements for managing salt-desert-shrub ranges in different condition classes.
- M Economics of land use by different classes of animals.

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